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Design and Implementation of the ESL Compact Range Underhung Bridge Crane

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As the indoor compact range technology has continued to increase, the need to handle larger and heavier targets has also increased. This need for target lifting and handling prompted the feasibility study of the use of an underhung bridge crane to be installed in the ESL compact range. This report documents both the design of the underhung bridge crane that was installed and the implementation of the design in the actual installation of the crane.

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Chapter 1

Introduction

The feasibility study of an underhung bridge crane in an indoor compact range was undertaken at the ESL. Initial concerns centered around the electromagnetic impact that a large moveable steel structure would have on the indoor compact range. It was determined that the underhung bridge crane would have to be specially designed from the outset to ensure suitable compatability with the indoor compact range.

After the unique designs for the electromagnetic compatability had been completed, focus moved to producing a crane that would have optimal handling characteristics for the target requirements encountered in the compact range. Finally, the implementation of these designs in the installation of the crane was carefully examined and carried out.

Chapter 2

Electromagnetic Evaluation

The electromagnetic aspects of a standard underhung bridge crane are of primary concern. The standard underhung bridge crane has two major components that must be evaluated from an electromagnetic viewpoint. These possible sources of electromagnetic scattering must be eliminated if an underhung bridge crane is to be feasible for a compact range.

The first major component is the travelling bridge portion of the crane and its associated structure. This structure spans the entire width of the compact range, and thereby presents a large surface capable of unwanted electromagnetic scattering. The associated componenets of the bridge are the hoist trolley, which traverses the bridge, and the hoist, which is attatched to the hoist trolley. Each of these items also present a moveable surface with related EM scattering.

The second major component is the runway beams that support the bridge assembly. These runway beams travel in the down range direction, parallel to the radar energy, and are located at the extreme widths of the chamber. While these are fixed beams, they represent possible sources of scattering to and from the pedestal or target. In addition, from a vector background subtraction viewpoint, they can deflect enough during the movement of the bridge assembly to become an area of concern.

I Bridge Assembly Evaluation

The sheer size of the bridge assembly dictated a complete electromagnetic shielding. In addition to the complete shield, the nature of the moving hoist and hoist trolley also required consideration. The proposed use of the crane included the storage of targets on on the crane during background measurements, and thus some shielding of the target during this phase of operation was desired. Figure 2.1 shows the absorber treatment to the bridge assembly. The addition of this shielding structure required fixed outriggers from the bridge end trucks for support.

The desire to maintain the maximum headroom, the available floor to crane distance, required that the wide absorber cover be kept to a practical minimum. The side baffles shown in Figure 2.1 allow for storing a target during a background measurement, while not impeding the crane headroom in the midsection of the crane, i.e., the pedestal region.

All of the components that were added to the bridge beam itself were carefully examined to keep the available headroom to a practical maximum. As a design guideline, the low point on the bridge hoist was chosen to be the desired low point on the bridge assembly. This design guideline was later considered in conjunction with another guideline, that the hoist be able to traverse a maximum cross range distance.

With these basic concerns solved, the impact of the bridge assembly on the electromagnetic capability of the compact range was adequately reduced. In addition, the use of the pulsed radar system and the range gate techniques [1] places the bridge assembly outside the range area during most measurements.

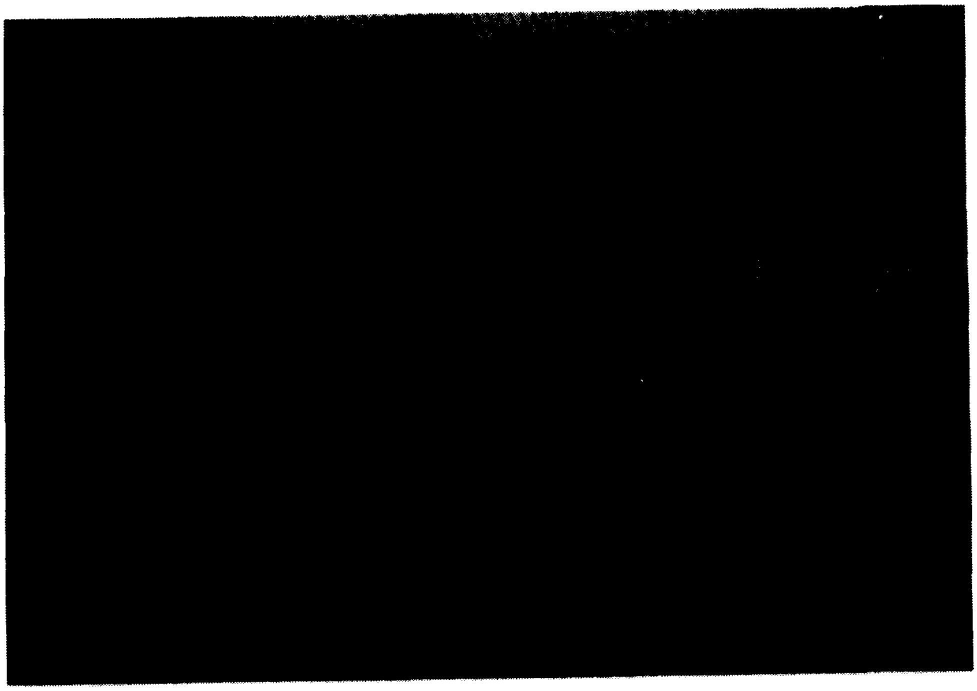

Figure 2.1: Front view of the bridge assembly with EM shielding in place.

II Runway Beam Evaluation

The location of the runway beams, which extend from the front to rear of the compact range, presented a difficult problem in the scattering of electromagnetic energy in the compact range. The range gate provides no assistance to this problem, since these beams extend the entire downrange length of the chamber. Thus these beams required special attention to hide them from electromagnetic illumination, while still allowing unimpeded access to the bridge crane end truck assembly.

It was decided that the ceiling would have be contoured to shield the runway beams. This drop in the existing ceiling thus required that the main bridge beam would have to be stooled down to provide the necessary clearance for the skirts. The slope of the ceiling in the chamber also dictated the amounts of stooling at the ends be different. Figure 2.2 shows the design that was chosen for the shielding. The angles and extent of the skirts were chosen based on shielding the runway beams from the diffractions at the upper corners of the compact range reflector, and from the rays perpendicular to the beams which might be scattered from a target placed on the pedestal.

III Underhung Crane Background Measurement

Since the underhung bridge crane is parked outside the range gate for the majority of measurements, the only additional concern was the effect of the underhung crane on the stability of the ceiling in the anechoic chamber. There existed the possibility of the weight of the crane disturbing the position of the ceiling between measurements when the crane had been moved from the parking place to the pedestal and back again. This concern stemmed from the fact that the roof and ceiling structure in our chamber is of nominal design, having the capacity of only 50 pounds per square foot loading.

To find out the impact of the crane on the ceiling, we performed a pair of background measurements, one prior and one after the movement of the crane from the parking place to the pedestal and back again. These two measurements were then subtracted from each other, and then calibrated. Figure 2.3 shows the case for the electric field vertically polarized, and Figure 2.4 shows the case for the electric field horizontally polarized.

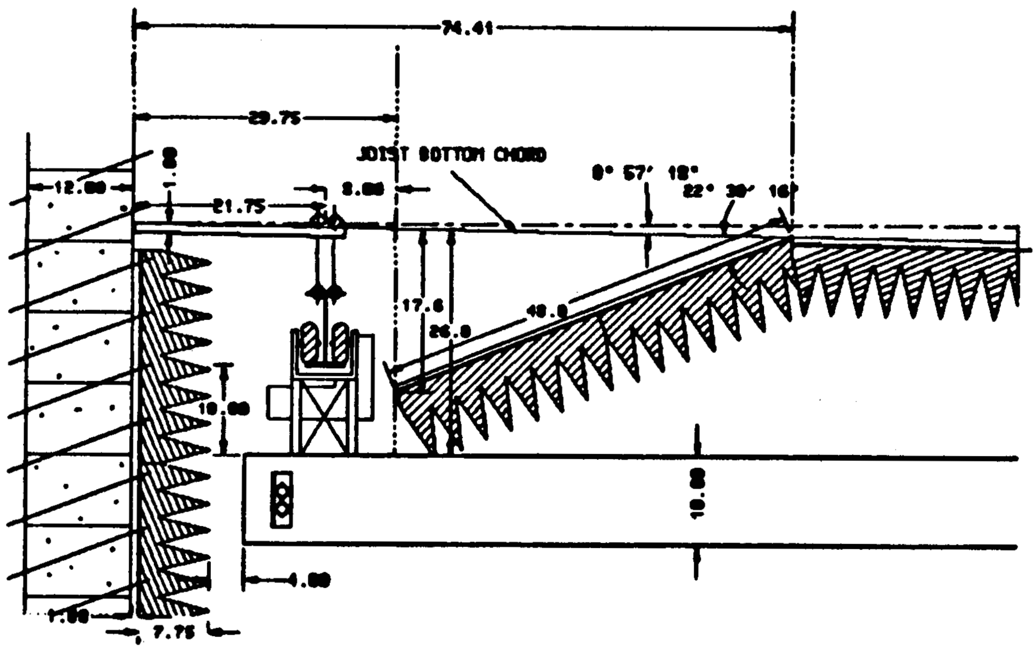

Figure 2.2: Absorber skirt cross section detail.

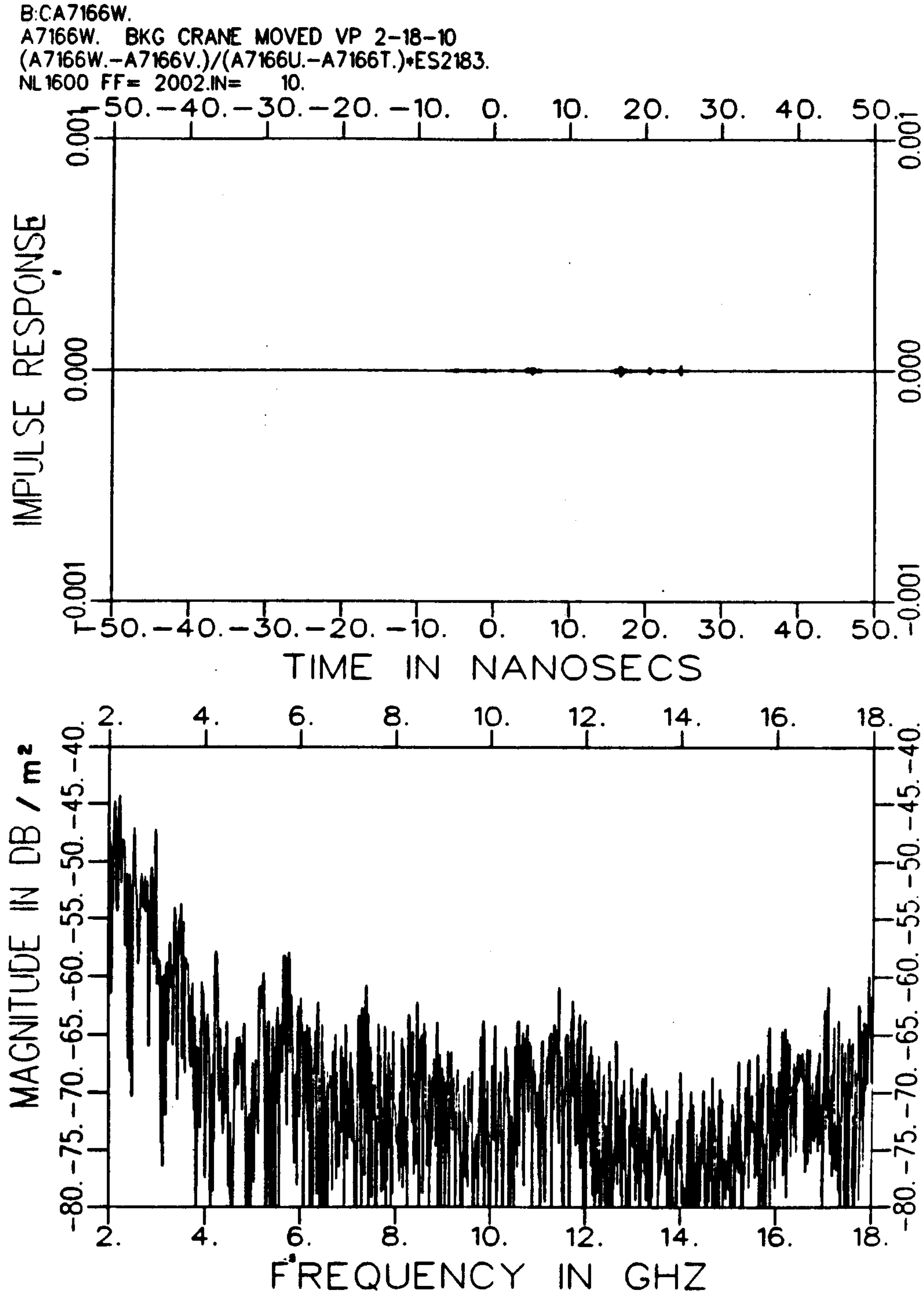

Figure 2.3: Backgrounds taken around the crane movement, vertical polarization.

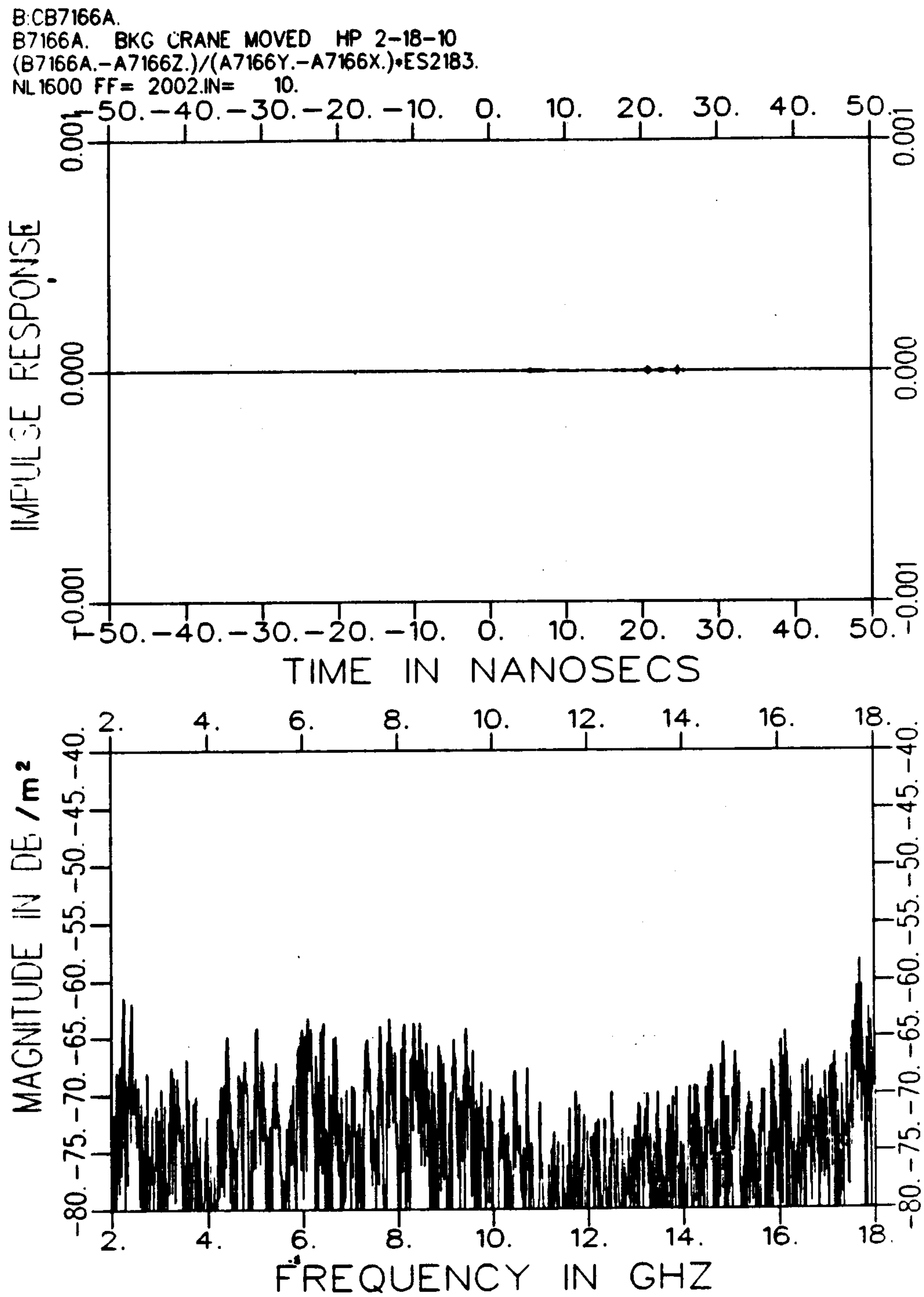

Figure 2.4: Backgrounds taken around the crane movement, horizontal polarization.

Chapter 3

Handling and Control Characteristics

Once the basic feasibility of an underhung bridge crane had been shown, there existed the need to design a crane tailored to the precise lifting and conveying needs encountered in the compact range facility. The standard production underhung bridge cranes were far too akward and abrupt for the handling requirements of the compact range. The ESL provided both design alterations to the underhung crane itself, and also designed and manufactured additional components to supplement the basic crane capabilities.

I Target Lifting and Conveying Demands

The indoor compact range poses unusual target lifting and conveying requirements for an underhung bridge crane. Traditional cranes are not intended to deal with fragile and sensitive loads, which are also light weight in comparison to the usual loads encountered in traditional crane environments.

A majority of the targets encountered in the compact range are electromagnetic models which require gentle, precise lifting means to convey the target from some storage area to the measurement area, which is traditionally a target pedestal. In addition, many of these targets are scale models which have been coated with a conductive paint, and thereby do not readily adapt to a chain sling type of conveyance.

Another important parameter to be considered is the precise need to locate the target at a fixed location at the pedestal. Thus the underhung crane must be able to precisely deliver the target to a defined location in the chamber. Again, the traditional underhung bridge crane has no provision to be able to locate precisely a point in the chamber.

The final consideration for the underhung bridge crane conveyance is the ability to deploy and remove a target from a pin and sleeve type of receptor for mounting the target to the pedestal. The traditional underhung crane uses a chain hoist to lift and lower loads, and this type of vertical movement was deemed unsuitable for our needs, thereby requiring a modification to the design and operation of the lifting of loads by the crane.

II Design Modifications and Additional Components

To solve the disparity between the commercially available features and the requirements posed by the indoor compact range, the ESL changed the design of the available underhung bridge crane where possible, and added special components to achieve the desired handling and conveying capabilities where modifications were not feasible or available.

These modifications included the addition of speed control in all axes of motion of the underhung bridge crane, the addition of acceleration and deceleration controls to all axes of motion, the addition of sensing mechanisms to limit the travel of the underhung bridge crane and to provide a parking limit for the crane when stored, the addition of a fully wireless remote control system for the operation of all features of the crane, and the manufacture of a fully variable lifting assist device to provide smooth lifting and lowering.

II.1 Speed Control and Acceleration/Deceleration Control

The first modification needed was the ability to easily place the target at an exact location on the pedestal. The standard underhung bridge crane has a single speed three phase squirrel cage motor which has undesirable performance both in acceleration/deceleration and in speed profiles.

The ESL decided to incorporate two speed three phase motors in all axes of movement to better control the positioning of the target. The problem encountered with standard motors is the inability to "creep" the load in any direction. The two speed arrangement allows for better overall postitioning of the load in the compact range, and with the reduced speed a closer approximation to creep can be realized.

To further improve the positional capabilities of the underhung bridge crane, electronic soft starts were installed on every winding of every motor in the installation. The soft start controls were purchased from Reuland Electric [2]. These controls were tuned to provide the best available ramping of torque and speed for smooth takeoff and stopping of the load in all axes of motion, thereby avoiding unnecessary jolting and swaying of the load.

II.2 Electronic Control System

The addition of the various components to the standard underhung bridge crane necessitated a simple wireless control system to manage the operation of the crane. The nature of the target handling in the compact range also requires freedom from the standard fixed pendant control, since there is a limited area on the floor where the operator may be located. The wireless remote control transmitter and receiver (series 2001) were supplied by Telemotive [3].

Another concern in the operation of the underhung bridge crane is the need to limit the overall excursion of the bridge assembly in the up- and downrange direction. In the case encountered here at the ESL, the runway beams extend the entire length of the range. Our compact range reflector sits only a few feet below the finished ceiling, thereby posing a hazard of the bridge assembly striking the reflector. In addition, our main access for large targets is near the downrange location of the reflector, thus requiring a close approach to the reflector. We solved this problem by including a limit switch assembly to both locations along the runway beams, one in the rear of the room where the crane is parked, and one near the reflector.

II.3 Variable Lifting Assist

The need to smoothly deploy and remove targets from a pin and sleeve type of mount required careful evaluation of available lifting assist devices commercially available. After examining those devices available, it was determined that none met the needs of the compact range.

To improve the lifting capabilities, the ESL designed and manufactured a hydraulic assist component. This lifting device is rated and load tested for a one (1) ton load. The component is controlled by the wireless remote control system, and the rate of lift/lower is controlled at the load point by a variable flow control device. The entire system was built on a slave trolley assembly which is connected to the hoist trolley, and the hydraulic cylinder attaches to the end of the chain hoist. Figure 3.1 shows the hydraulic schematic of the system, and Table 3.1 lists the components and their manufacturer.

The hydraulic system was assembled here at the ESL, and layout of the package was designed to have a minimum amount of overall height, so as to maintain the maximum available headroom for the underhung bridge crane. The layout necessitated the addition of a slave trolley assembly, which houses not only the variable lifting assist package, but also the electronic soft start controls for the hoist trolley and hoist and the electronics cabinet in which the control logic and wiring is housed. Figure 3.2 shows the layout of the various components on the slave trolley.

II.4 Universal Target Mount

It is the goal of this design to accomodate the larger targets that are being encountered in the compact range. In addition to the physical size, there are stringent requirements on target stability in all axes of motion. To meet these requirements, this design incorporates a number of simple features to allow for ease of handling to and from the pedestal, as well as stable and secure mounting to our low cross section target pedestal.

The universal mounting concept is based on the desire to reuse the same mounting post and accessories for a variety of targets, requiring that a minimum of mounting materials be generated each time a new model or target is manufactured. Only the universal mount receiver and the blank plug need be made for each target, and these are shaped by the model maker to suit the individual target or model.

To understand the basic support and lifting concepts, Figures 3.3 through 3.10 illustrate the components. The receivers are located inside the target or body, and they connect to the universal post for support and the bayonet for lifting and carrying the target or model. The blank plug is designed to cover the hole when the receiver is unused during measurement.

Universal Mount Receiver

The external dimensions and shape of the universal mount receivers, which are located inside the target, are variable to fit the requirements of the target, and the contour of the receiver faces can be shaped to the contour of the target, or be recessed into the body. The receivers should also have some sort of pressure relief mechaninsm to allow ease of insertion and removal of the support post and blank plug, such as the air hole shown.

Machining tolerances here are extremely important to insure a stable mating of the support post and the receiver. In addition, the receivers should be located in the same axis, i.e., one above another to allow the bayonnet to easily remove the target from the post without binding forces. Each receiver is identical, and the bayonnet and support post will fit the same receiver. This also insures that the minor scattering associated with the blank plug will be located in the same down range location as the pedestal support post.

Physical and Structural Considerations

In selecting the mount versions, entitled the *"A" Series* and the *"B" Series*, target weights and mechanical stresses should be evaluated. The *"A" Series* mount is based on a nominal half inch diameter post, whereas the *"B" Series* is a nominal one inch diameter post.

The means of attachment of the receivers to the internal structure must be strong enough to allow the target to be supported and rotated on the pedestal, and also allow the bayonnet to lift and carry the target to and from the target pedestal.

Blank Plug Contour

The blank plug, which is used to cover the receiver hole after the bayonnet is removed, should have a contour which closely matches the surface of the target, whether the receiver is flush with the surface or recessed. This will insure that the scattering from the plug will be minimized. Each receiver should have an accompanying blank plug for this purpose.

The basic universal mounting scheme presented here will allow simple reuse of a stable hard mounting technique. Only the body related components, i.e., the receivers and blank plugs, need be generated for each target. Two series of mounts are available to handle the vast majority of targets anticipated on our low cross section ogival pedestal, and the interchangability of the receivers will allow various positions to be realized with a single mounting scheme.

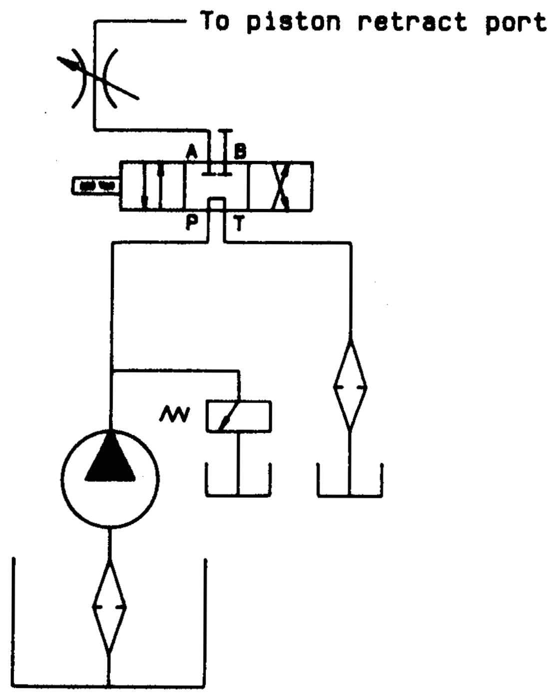

Figure 3.1: Hydraulic assist schematic.

AC Hydraulic Power Pack & Motor	Grainger # 7Z766
Solenoid Control Valve	Grainger # 2A126
Subplate	Grainger # 1A323
Industrial Hydraulic Cylinders:	
4" stroke	Grainger # 4Z638
8" stroke	Grainger # 4Z640
Clevis End Mounts (2 req'd.)	Grainger # 1A334
Clevis Rod Mounts (2 req'd.)	Grainger # 1A347
Automatic Hose Reel	Grainger # 4Z174
Control Valves (2 req'd.)	Grainger # 1A247
Hydraulic Couplings:	
Complete Coupling Set	Aeroquip # FD49-1000-06-06
Male Half	Aeroquip # FD49-1002-06-06
Misc. Hoses & Fittings	

Table 3.1: Hydraulic assist parts list.

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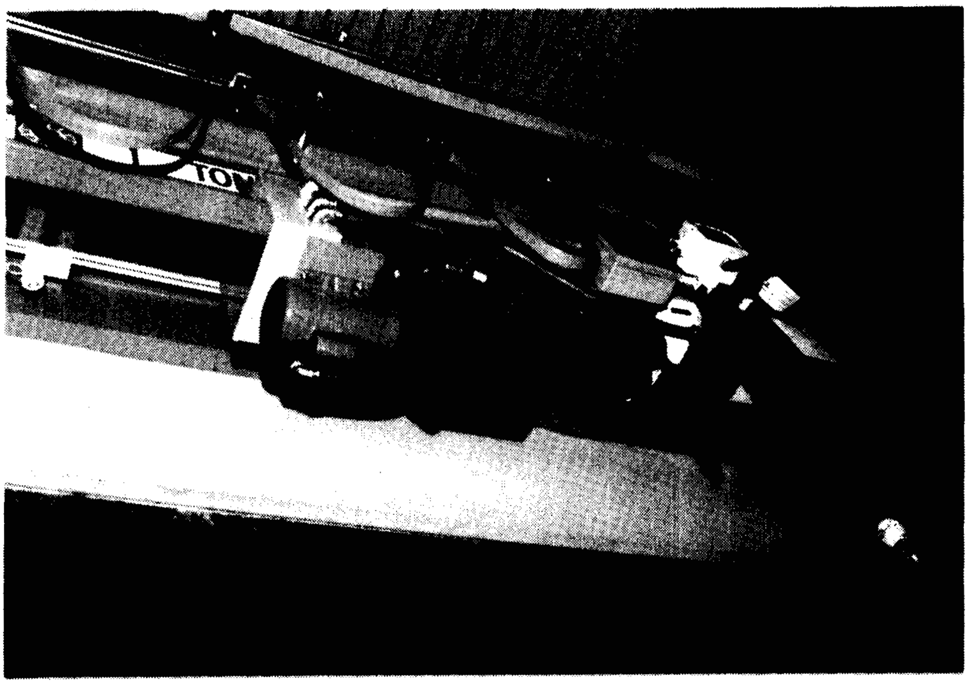

Figure 3.2: Slave trolley layout.

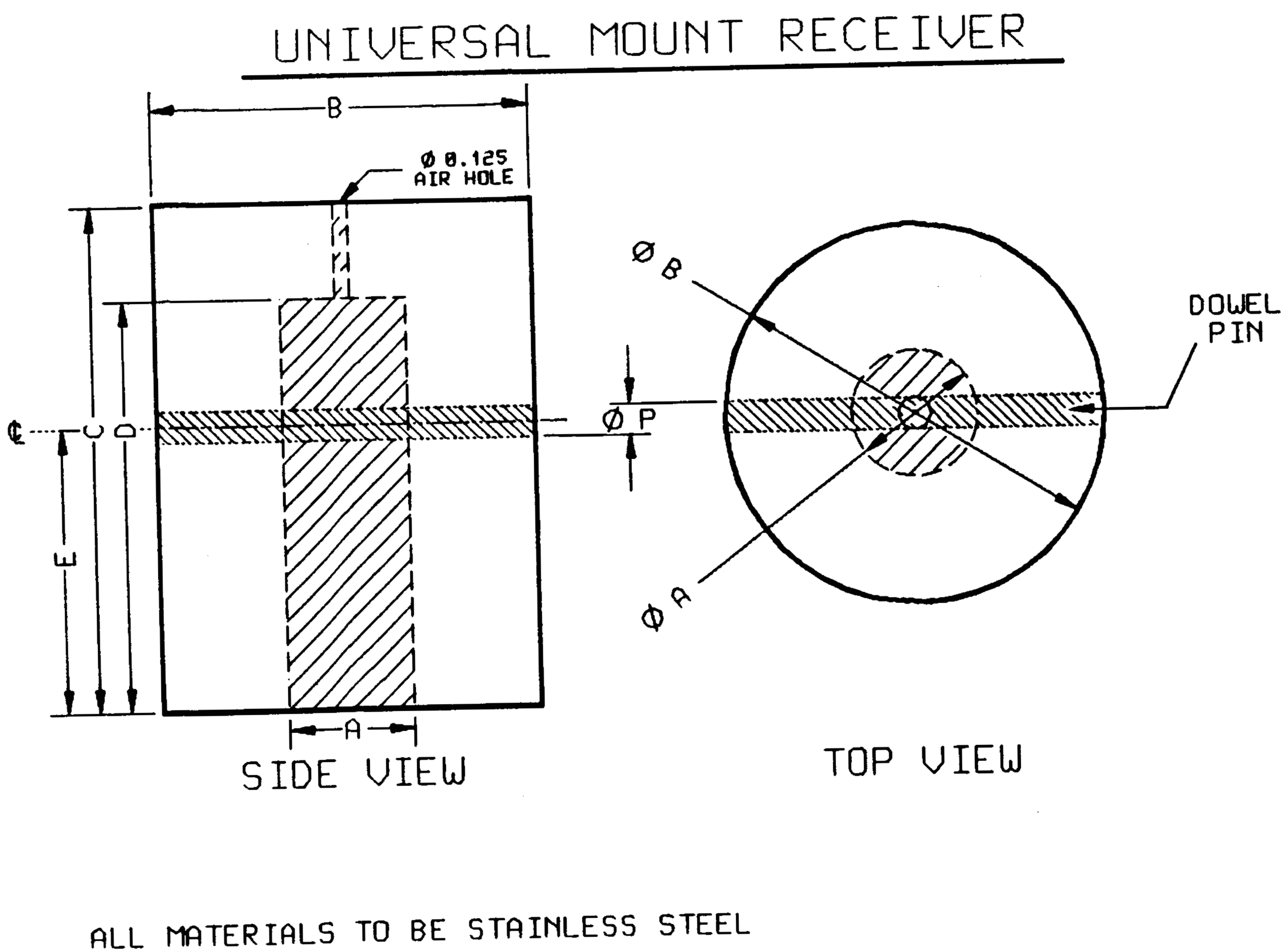

Figure 3.3: Universal mount receiver.

RECEIVER DIMENSIONS

DIMENSION	"A" SERIES MOUNT INCH/TOLERANCE	"B" SERIES MOUNT INCH/TOLERANCE	COMMENTS
A	0.503/+0.0000 -0.0005	1.003/+0.0000 -0.0005	MACHINE FIT TO DIM. H ON POST
B	VARIABLE, >1.000	VARIABLE, >2.000	SIZE AND SHAPE TO SUIT TARGET
C	VARIABLE, >2.500	VARIABLE, >3.500	SIZE AND SHAPE TO SUIT TARGET
D	2.000/ ±0.010	3.000/ ±0.010	FLAT BEARING SURFACE
E	1.250/ ±0.010	1.250/ ±0.010	
Ø P	0.1875/ +0.0002	0.3750/ +0.0002	MACHINE FIT TO DIM. I ON POST PRESS FIT

Figure 3.4: Universal mount receiver dimensions.

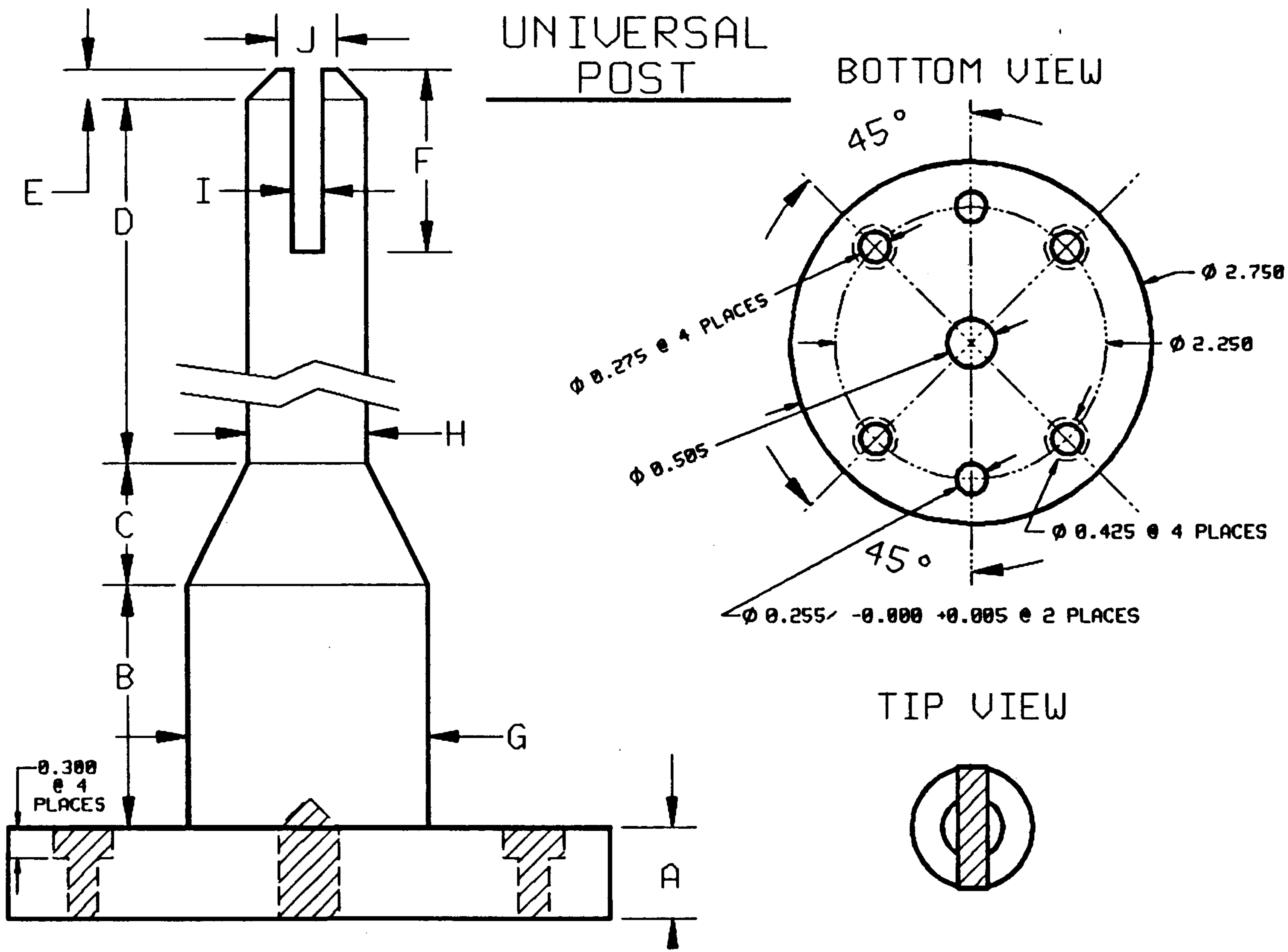

Figure 3.5: Universal mount post.

POST DIMENSIONS

DIMENSION	"A" SERIES MOUNT INCH/TOLERANCE	"B" SERIES MOUNT INCH/TOLERANCE	COMMENTS
A	0.500/ ±0.010	0.500/ ±0.010	
B	3.000/ ±0.010	3.000/ ±0.010	
C	1.000/ ±0.010	1.000/ ±0.010	
D	7.875/ ±0.010	7.750/ ±0.010	
E	0.125/ ±0.010	0.250/ ±0.010	
F	1.000/ ±0.010	2.000/ ±0.010	
G	1.000/ ±0.010	1.500/ ±0.010	
H	0.500/+0.0005 -0.0000	1.000/+0.0005 -0.0000	MACHINE FIT TO DIM. Ø A ON RCV
I	0.1885-0.1905	0.3760-0.3780	MACHINE FIT TO DIM. Ø P ON RCV
J	0.250/ ±0.010	0.500/ ±0.010	

Figure 3.6: Universal mount post dimensions.

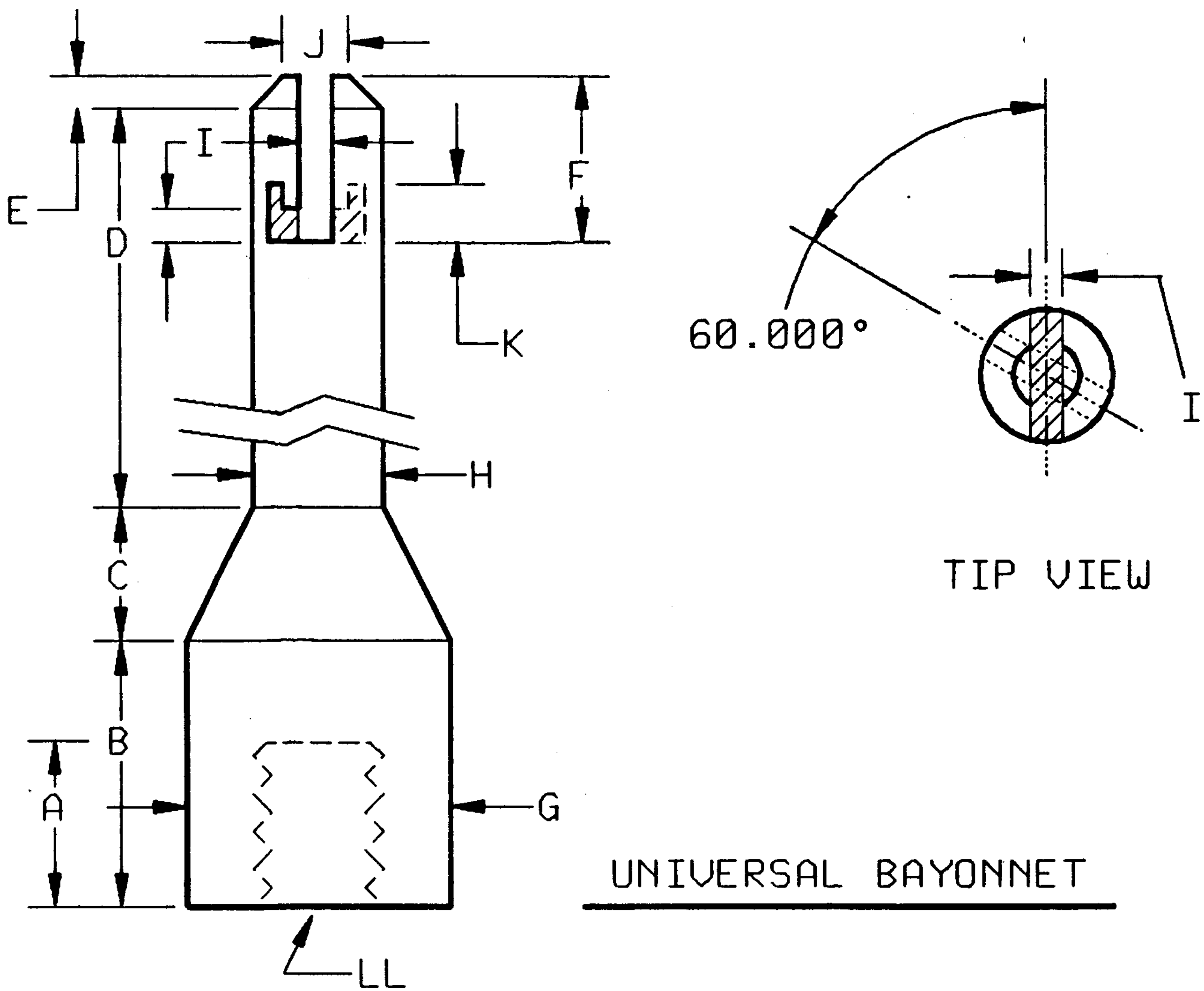

Figure 3.7: Universal mount bayonnet.

BAYONNET DIMENSIONS

DIMENSION	"A" SERIES MOUNT INCH/TOLERANCE	"B" SERIES MOUNT INCH/TOLERANCE	COMMENTS
A	1.250/ ±0.010	1.250/ ±0.010	
B	5.000/ ±0.010	5.000/ ±0.010	
C	1.000/ ±0.010	1.000/ ±0.010	
D	11.875/ ±0.010	11.750/ ±0.010	
E	0.125/ ±0.010	0.250/ ±0.010	
F	1.000/ ±0.010	1.830/ ±0.010	
G	1.500/ ±0.010	2.000/ ±0.010	
H	0.500/ ±0.010	1.000/ ±0.010	
I	0.200/ ±0.010	0.400/ ±0.010	
J	0.250/ ±0.010	0.500/ ±0.010	
K	0.350/ ±0.010	0.700/ ±0.010	
LL	3/4 X 16 THREAD	3/4 X 16 THREAD	BOTTOM TAPPED

Figure 3.8: Universal mount bayonnet dimensions.

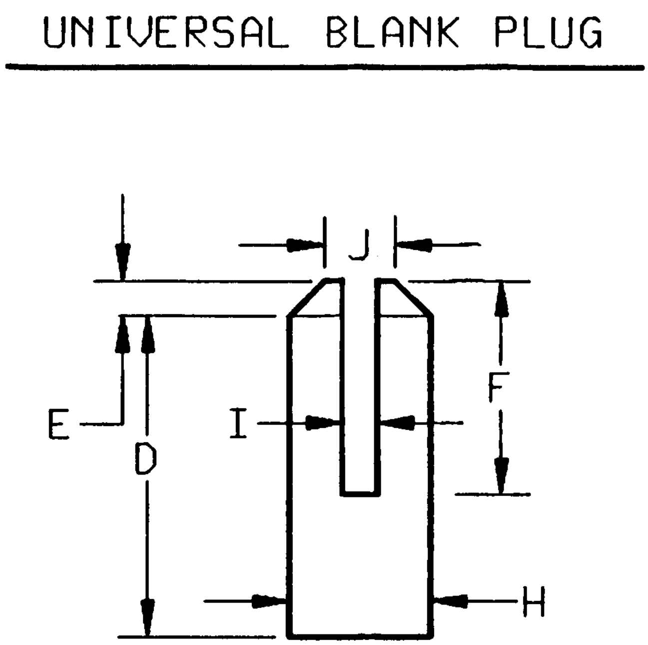

Figure 3.9: Universal mount blank plug.

BLANK PLUG DIMENSIONS

DIMENSION	"A" SERIES MOUNT INCH/TOLERANCE	"B" SERIES MOUNT INCH/TOLERANCE	COMMENTS
D	2.000	3.000	MACHINE PLUG TO TARGET SURFACE
E	0.125/ ±0.010	0.250/ ±0.010	
F	1.000/ ±0.010	2.000/ ±0.010	
H	0.500/ +0.0005 -0.0000	1.000/ +0.0005 -0.0000	MACHINE FIT TO DIM. Ø A ON RCV
I	0.1885-0.1905	0.3760-0.3780	MACHINE FIT TO DIM. Ø P ON RCV
J	0.250/ ±0.010	0.500/ ±0.010	

Figure 3.10: Universal mount blank plug dimensions.

Chapter 4

Underhung Bridge Crane Schematics

The following pages detail the wiring modifications to the underhung bridge crane, which was supplied by Spanmaster [6]. All of the additional wiring was done here at the ESL, with the assistance of the installing contractor, Ohio Crane and Hoist Co. [7].

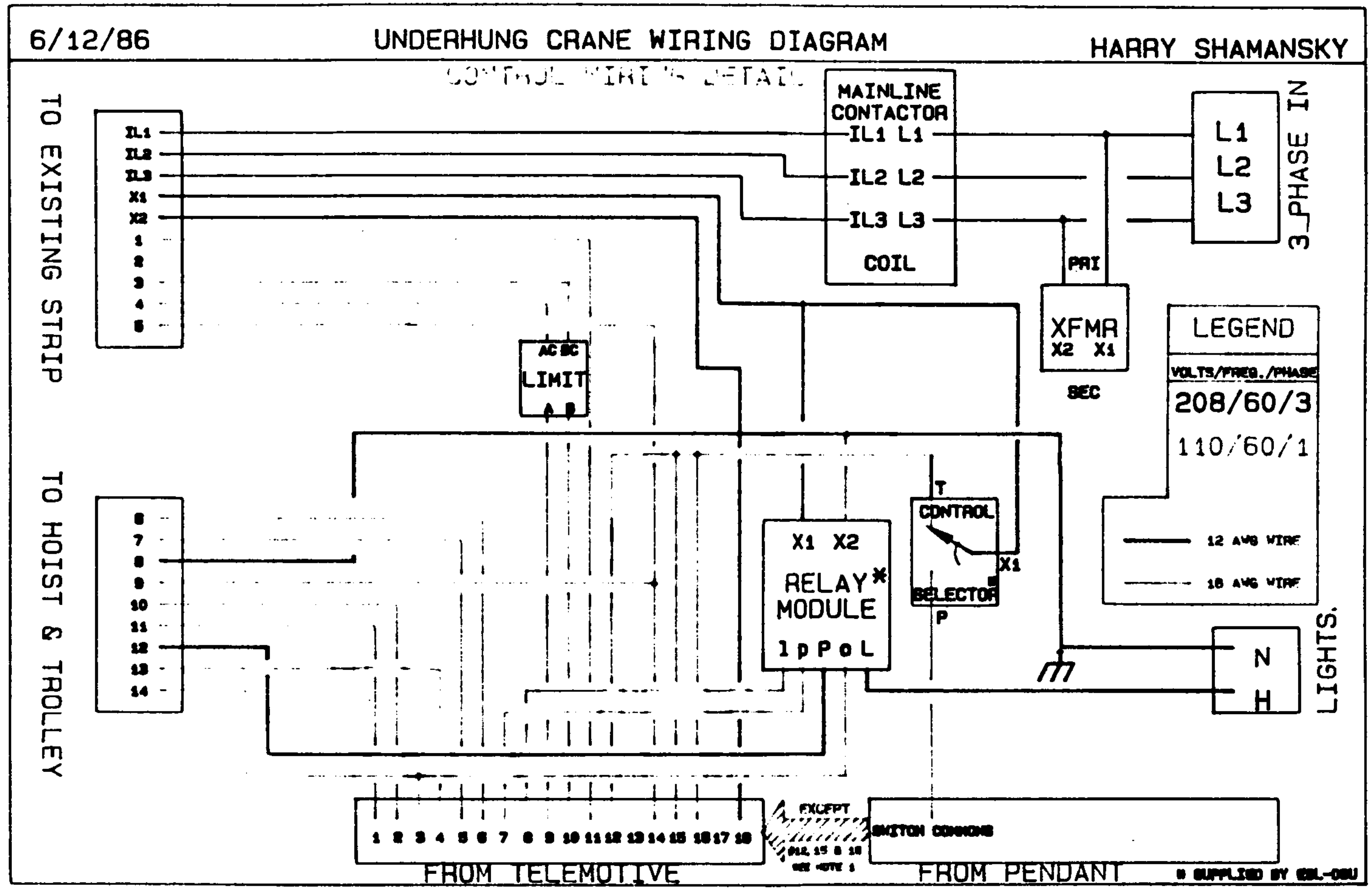

Figure 4.1: Underhung bridge crane schematic, control wiring detail.

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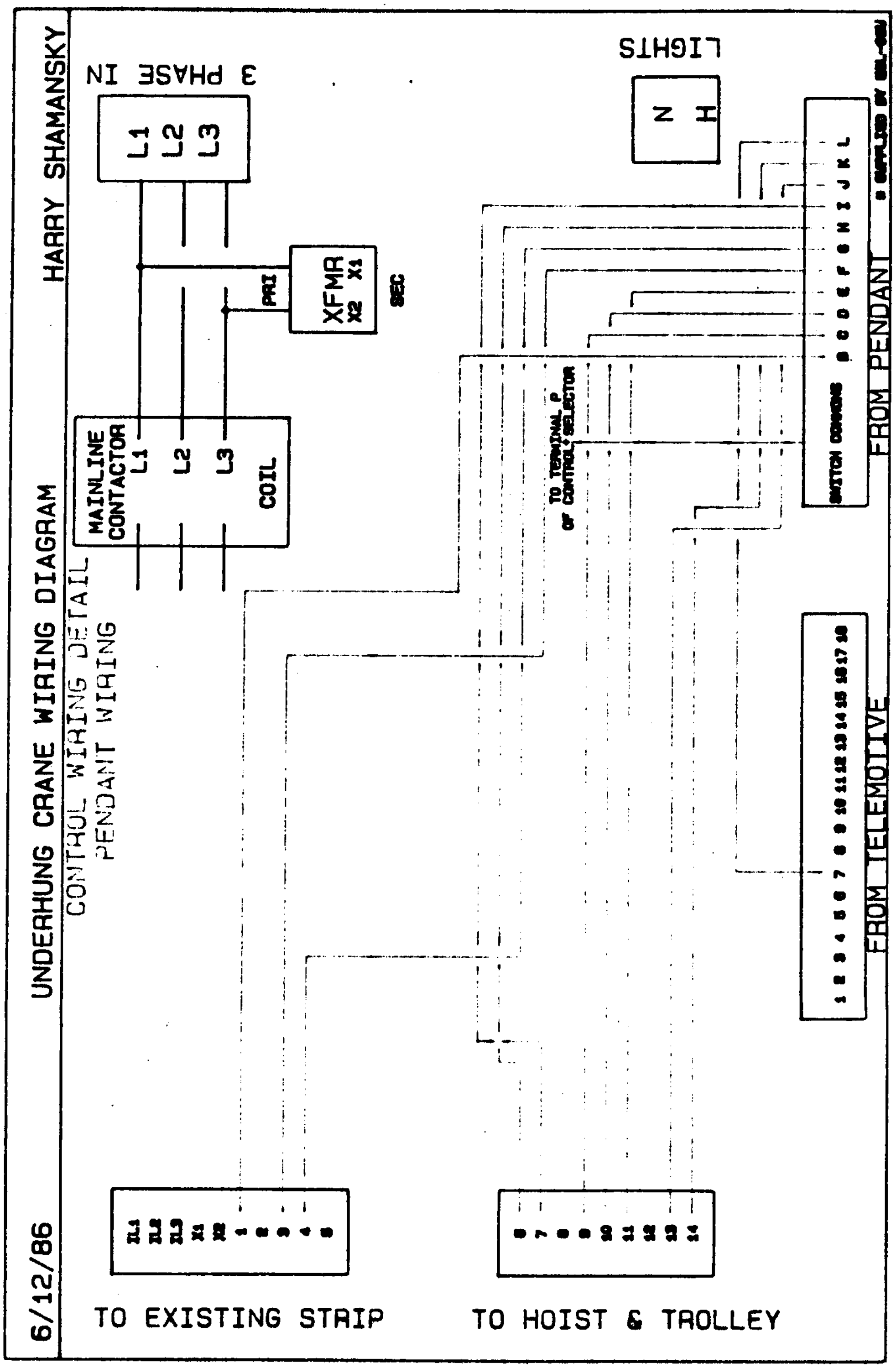

Figure 4.2: Underhung bridge crane schematic, pendant wiring detail.

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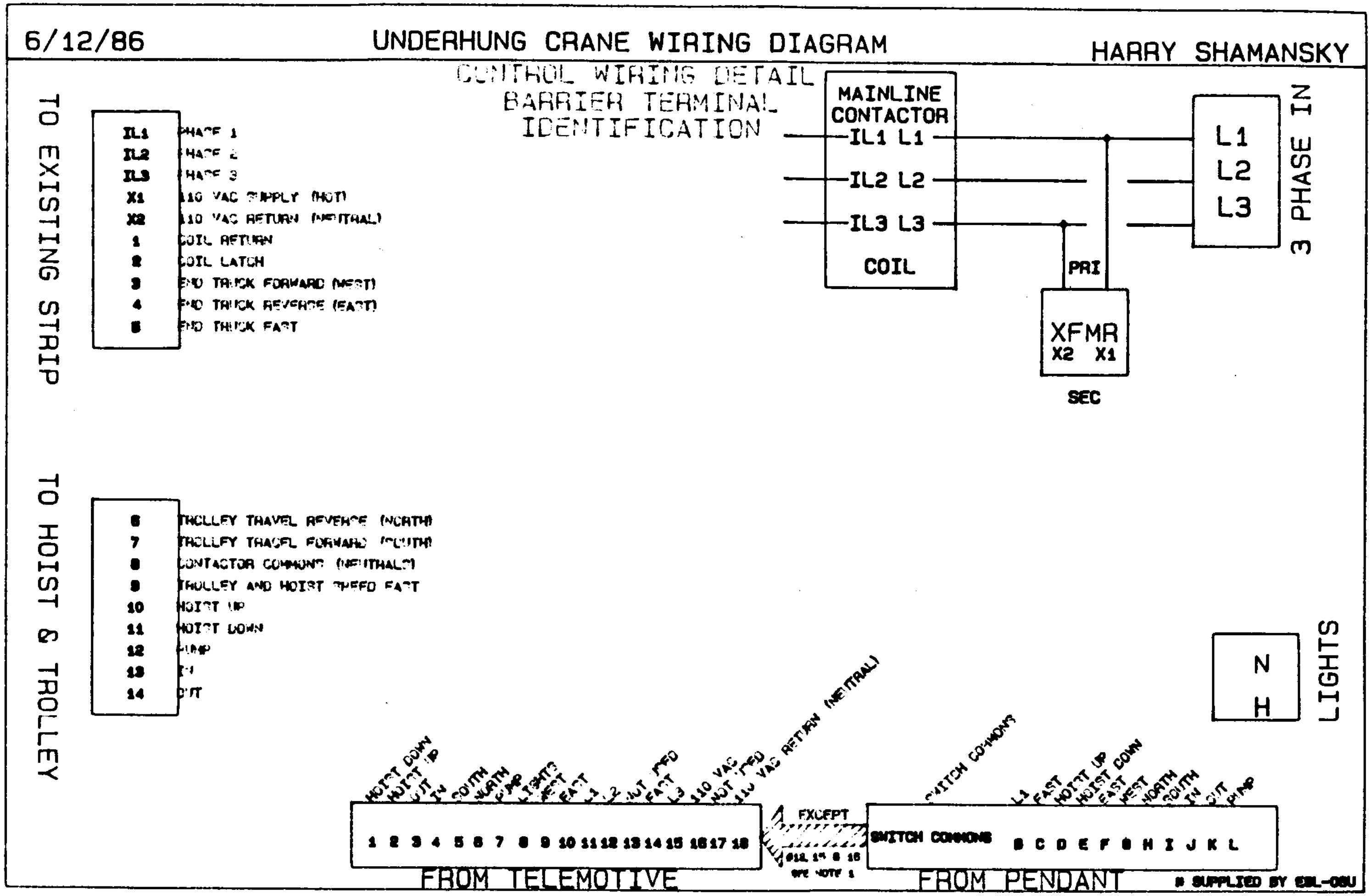

Figure 4.3: Underhung bridge crane schematic, barrier terminal identification.

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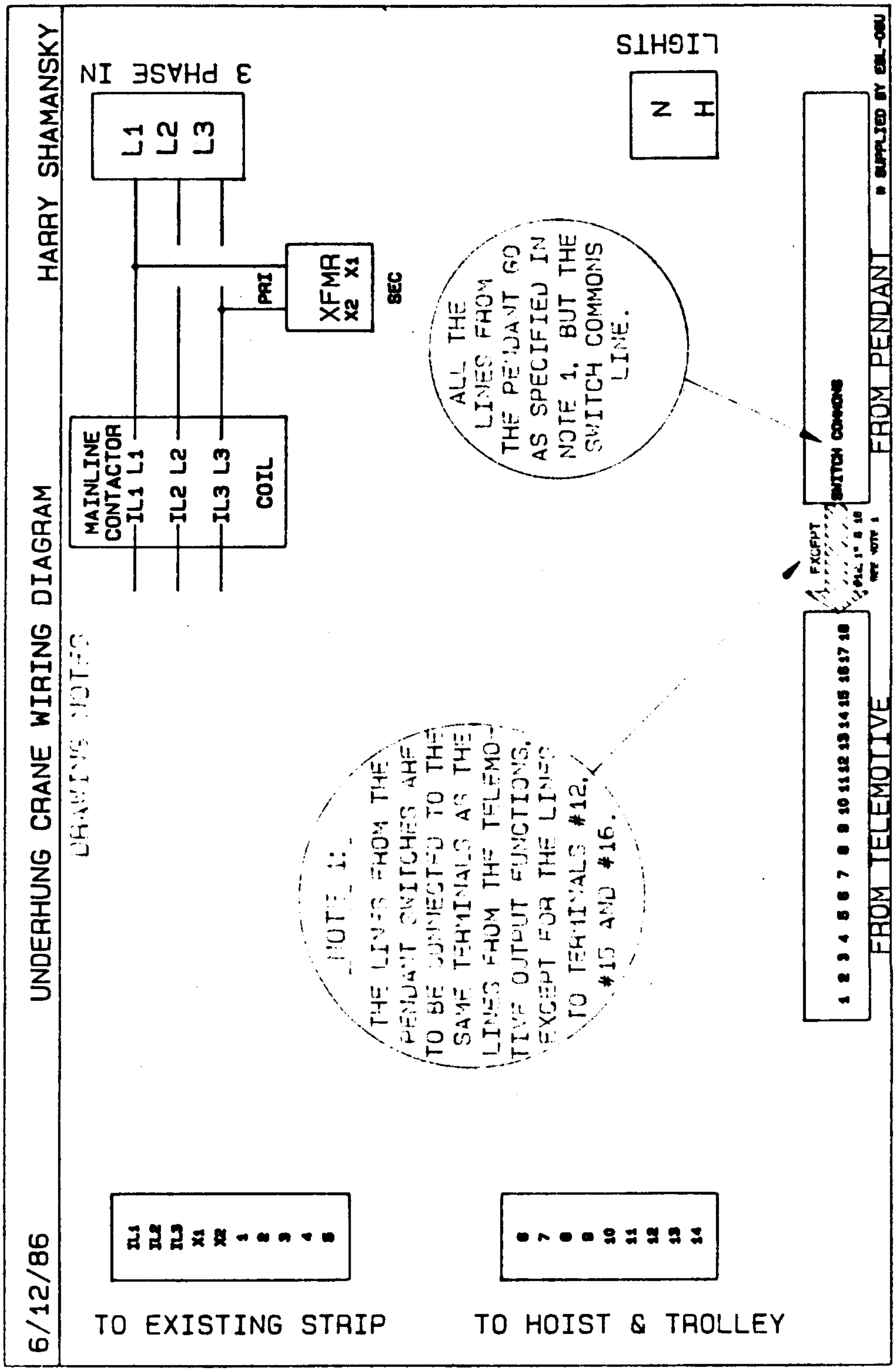

Figure 4.4: Underhung bridge crane schematic, drawing notes.

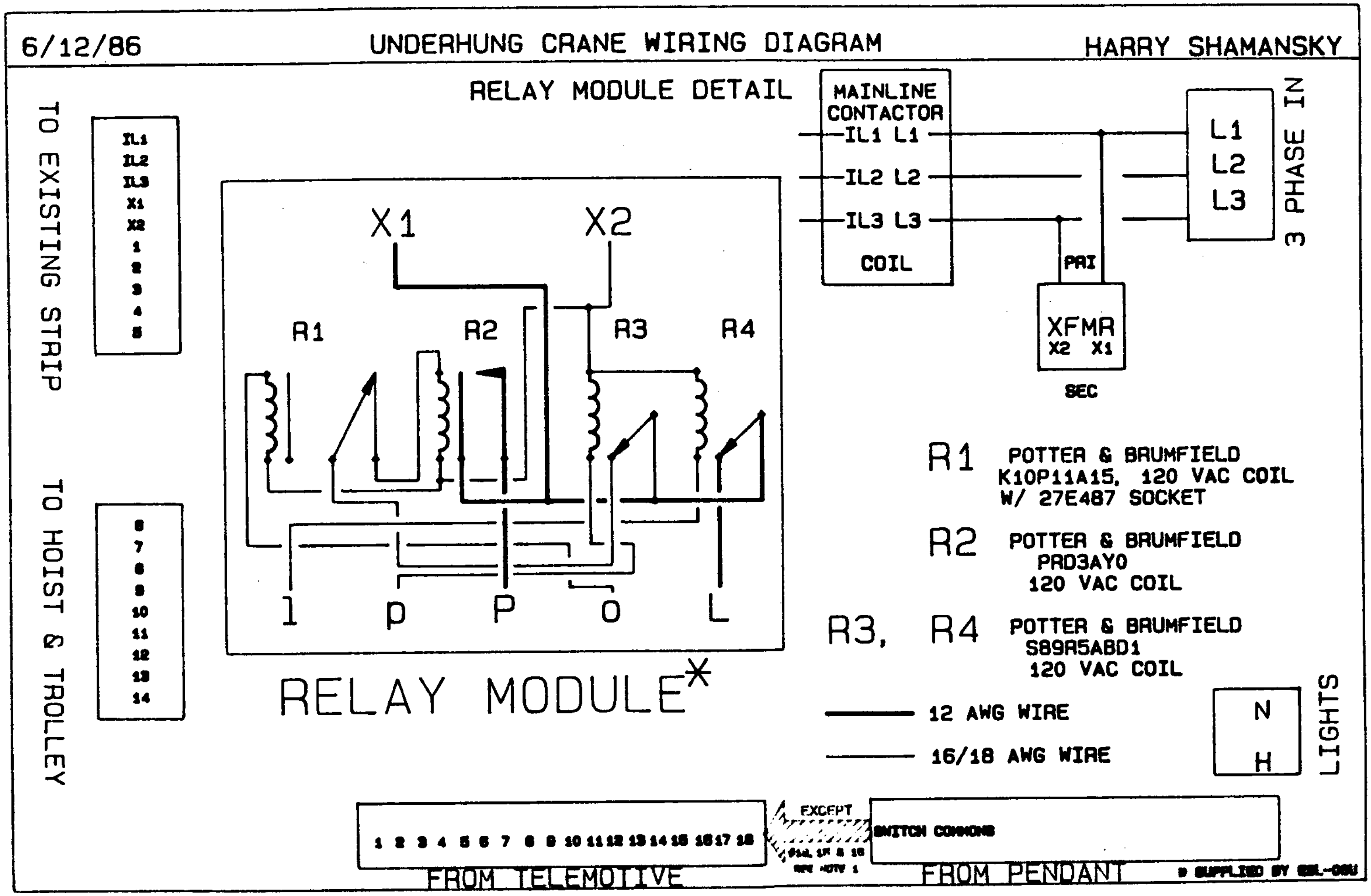

Figure 4.5: Underhung bridge crane schematic, relay module detail.

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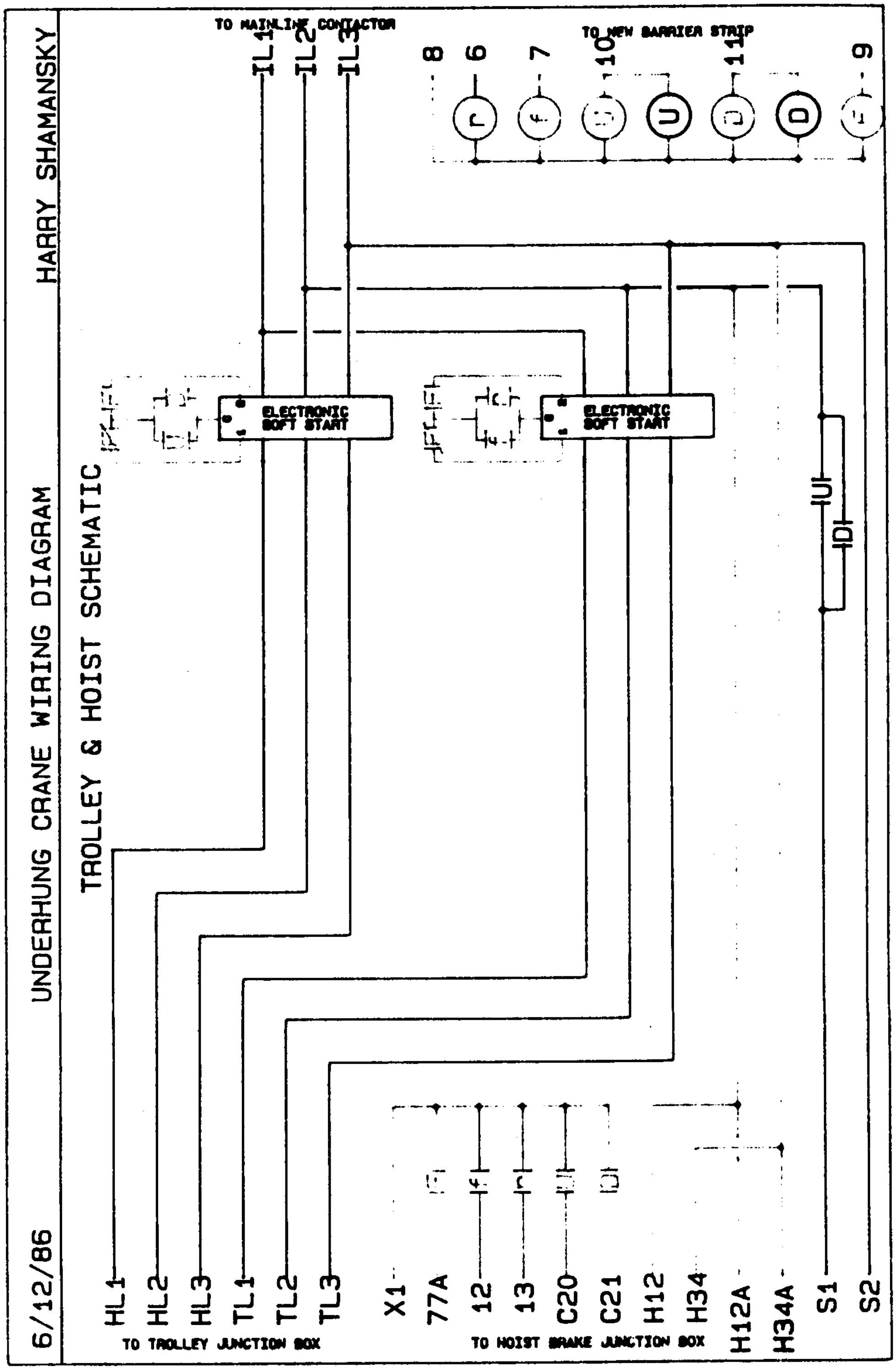

Figure 4.6: Underhung bridge crane schematic, trolley and hoist.

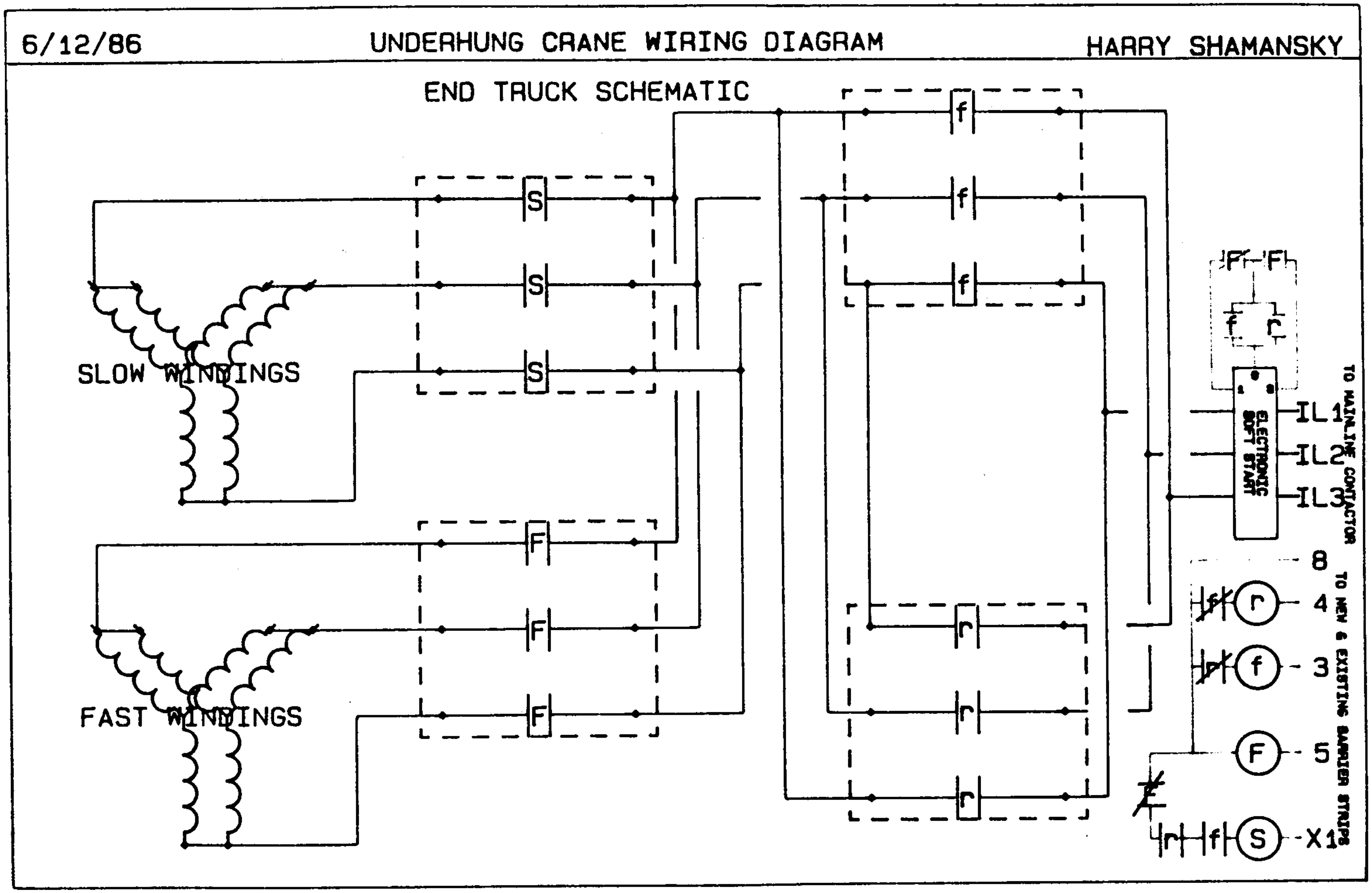

Figure 4.7: Underhung bridge crane schematic, end truck.

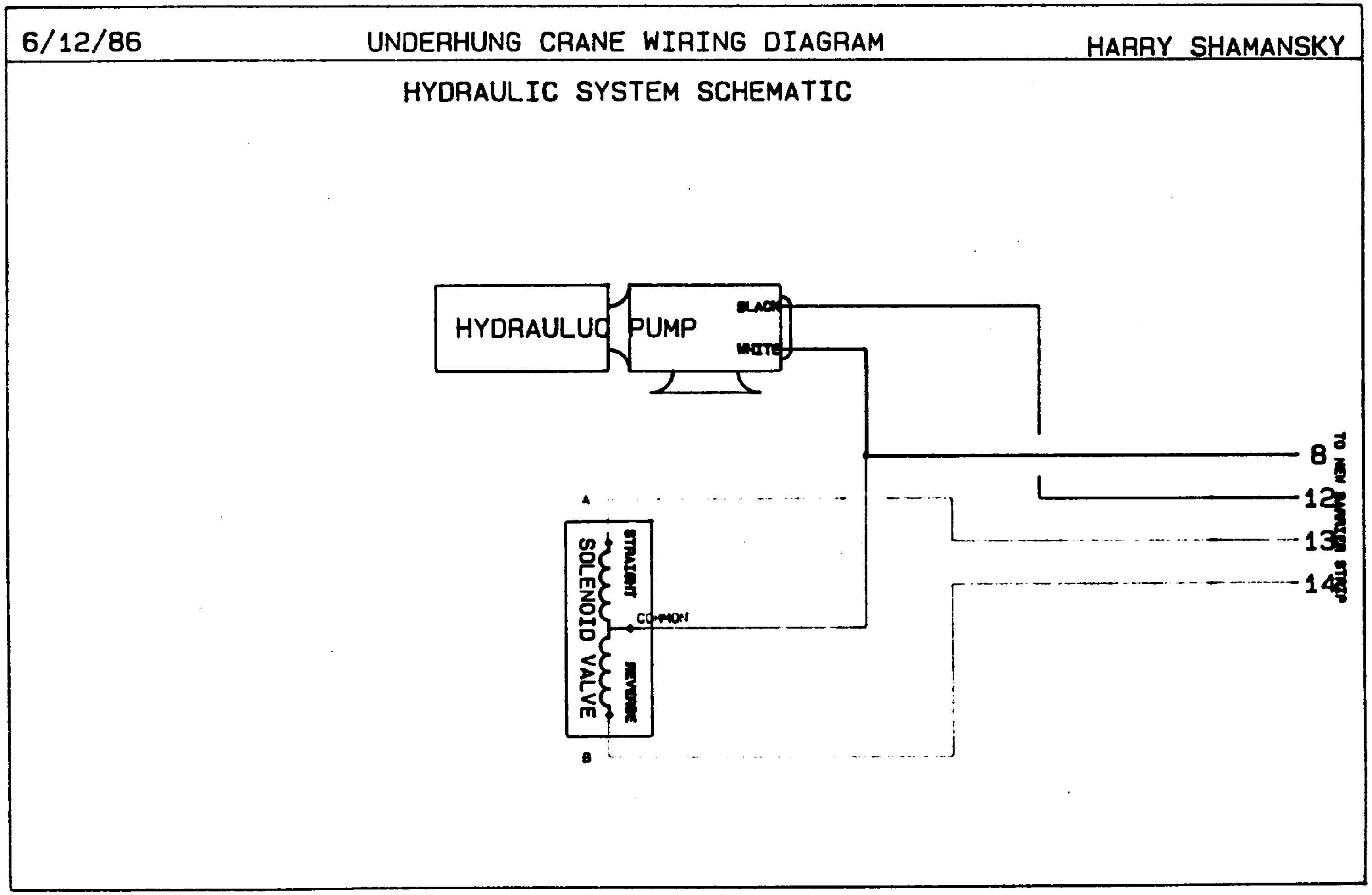

Figure 4.8: Underhung bridge crane schematic, hydraulic system.

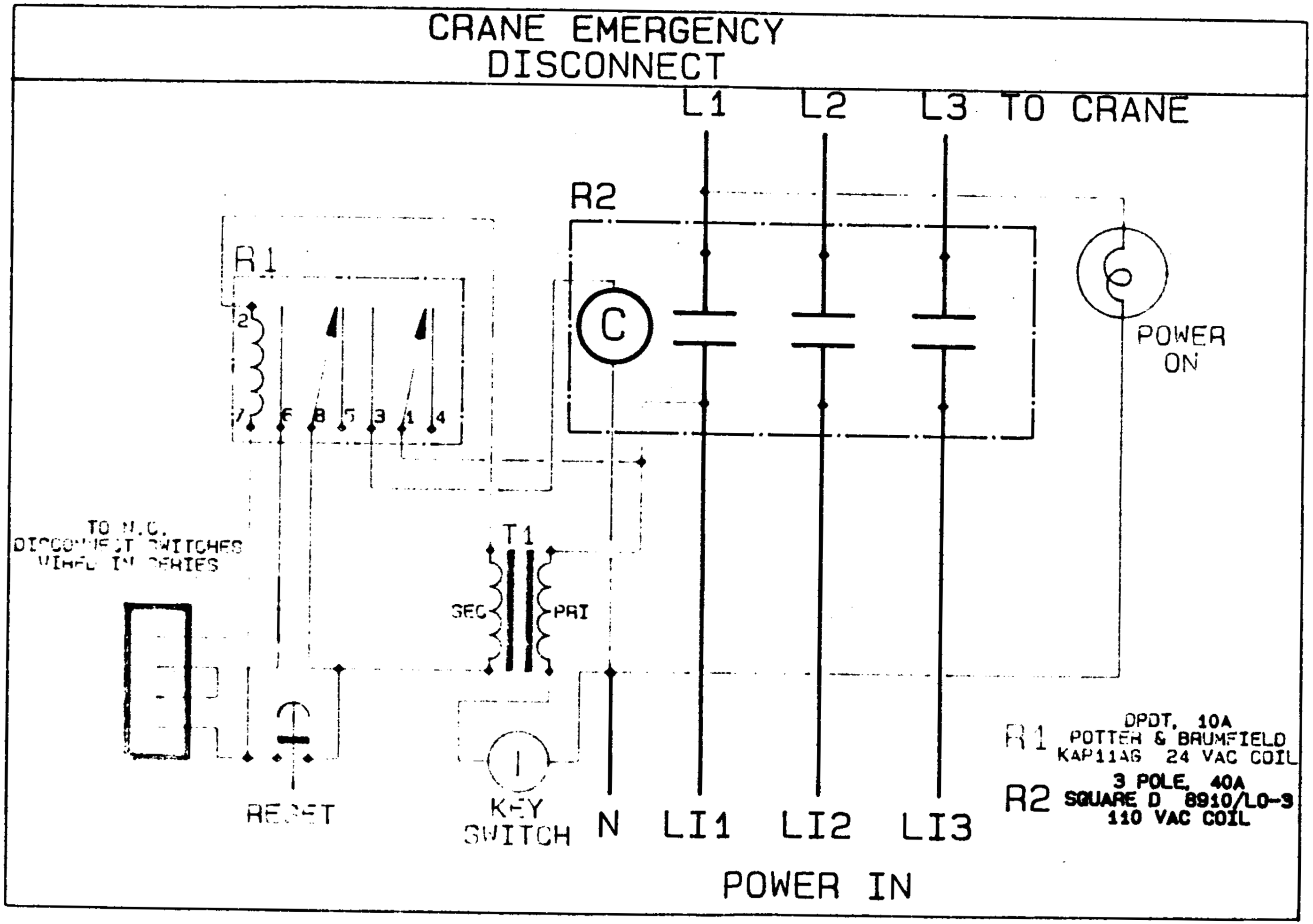

Figure 4.9: Underhung bridge crane schematic, crane emergency disconnect.

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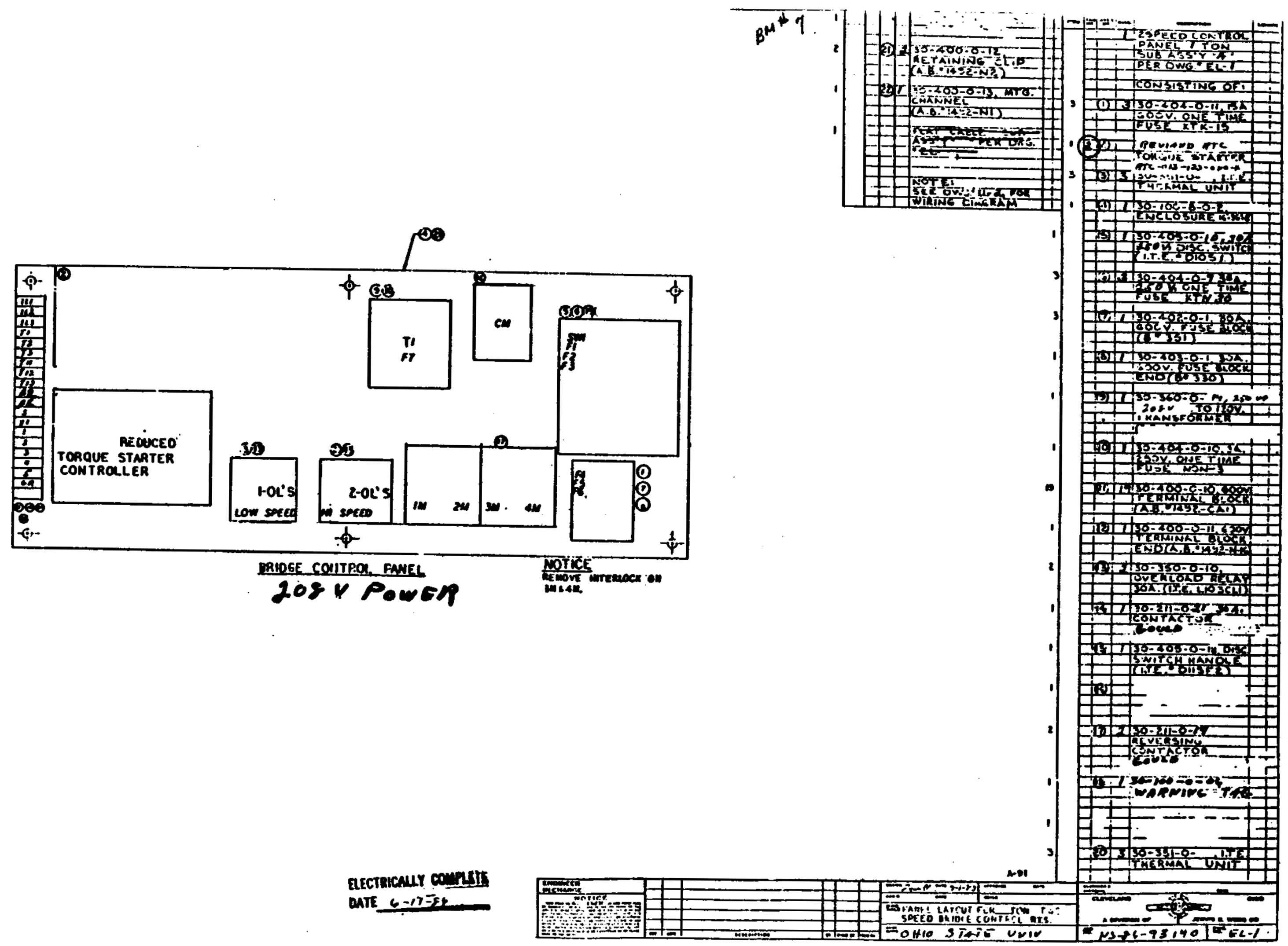

Figure 4.10: Underhung bridge crane schematic, panel layout, existing.

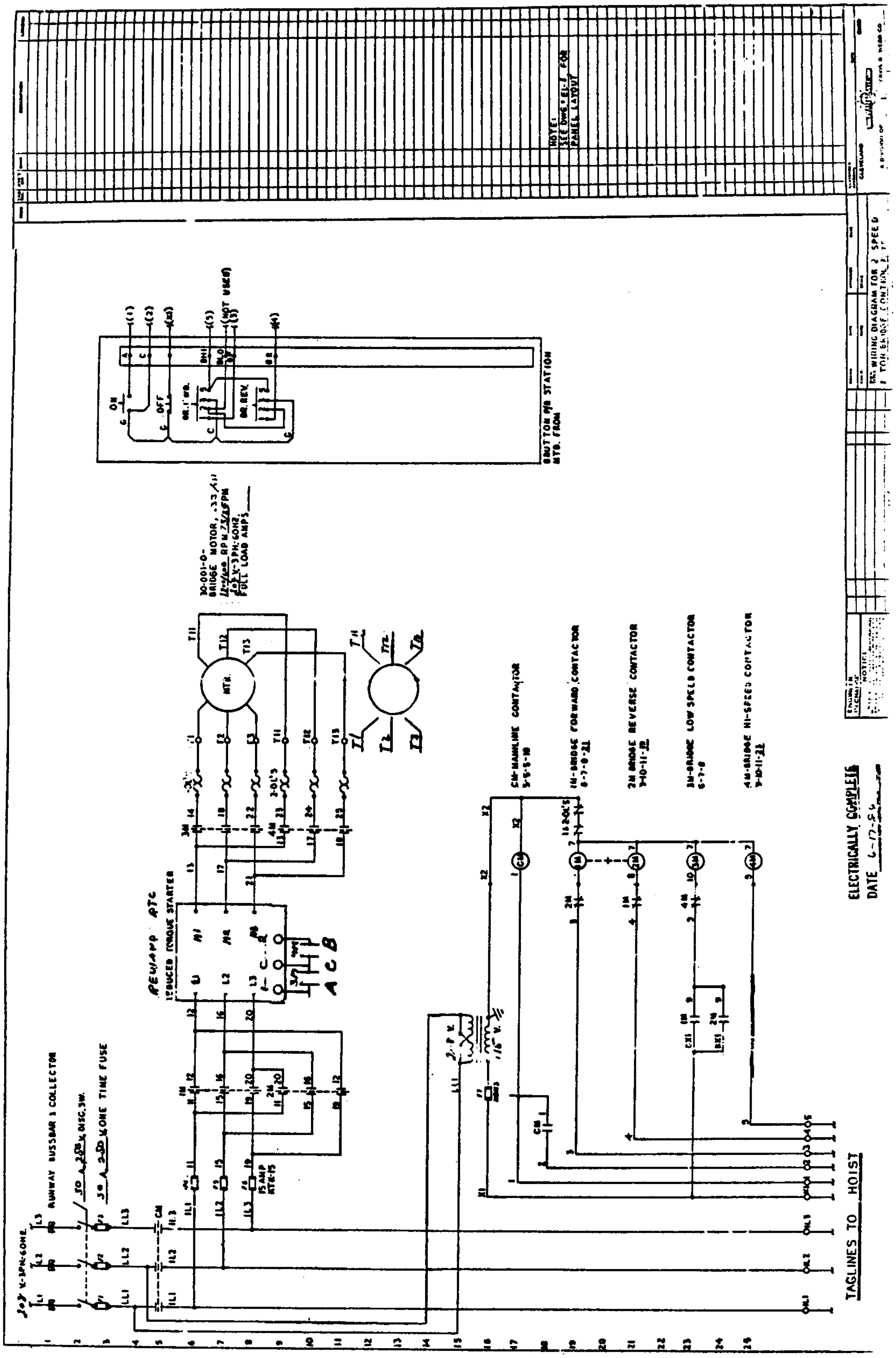

Figure 4.11: Underhung bridge crane schematic, two speed layout, existing.

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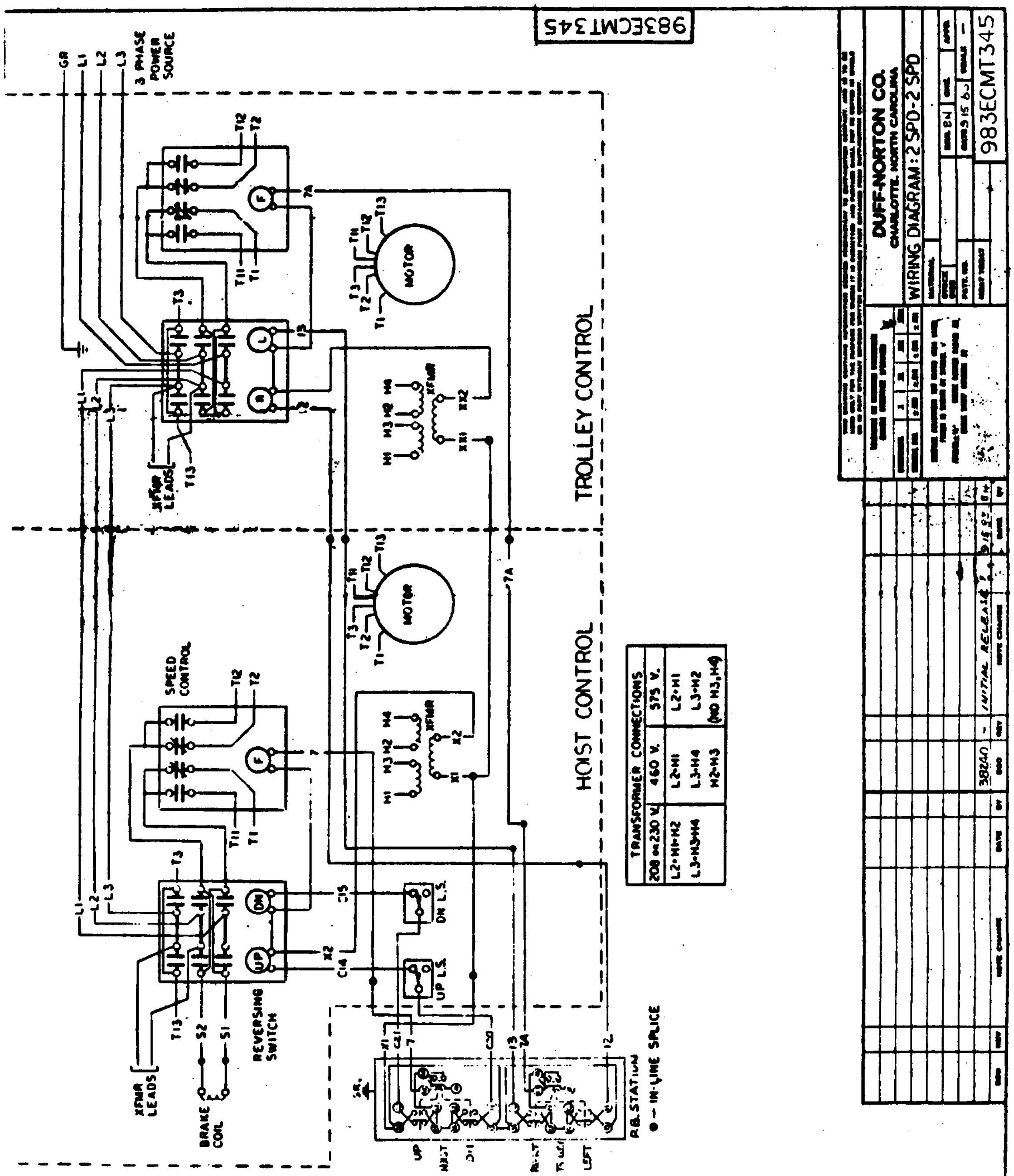

Figure 4.12: Underhung bridge crane schematic, hoist and trolley, existing.

Chapter 5

Underhung Bridge Crane Drawings

The following two figures show the drawings supplied by Spanmaster for the underhung bridge crane installed in our anechoic chamber.

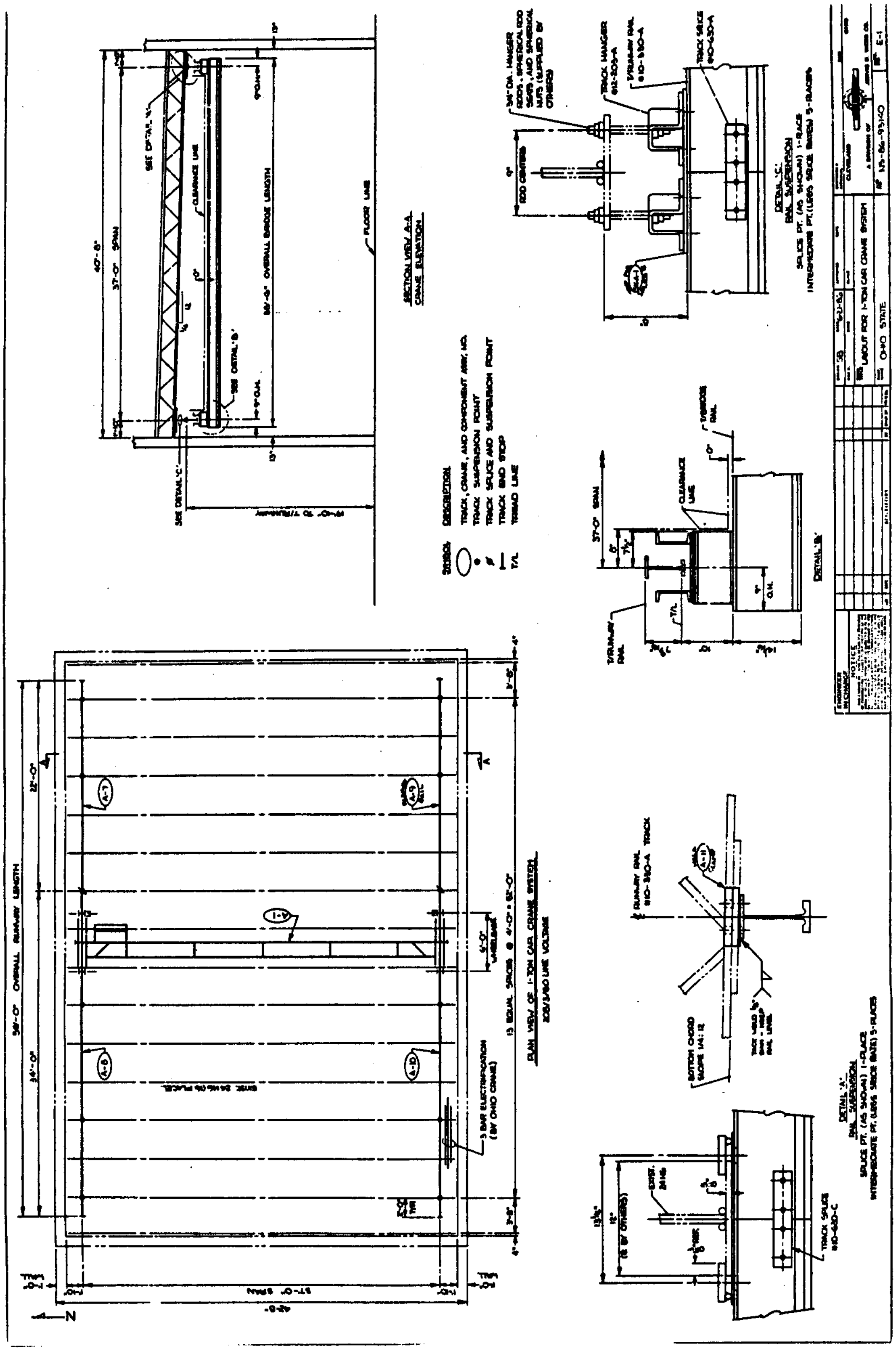

Figure 5.1: Underhung bridge crane drawing, layout.

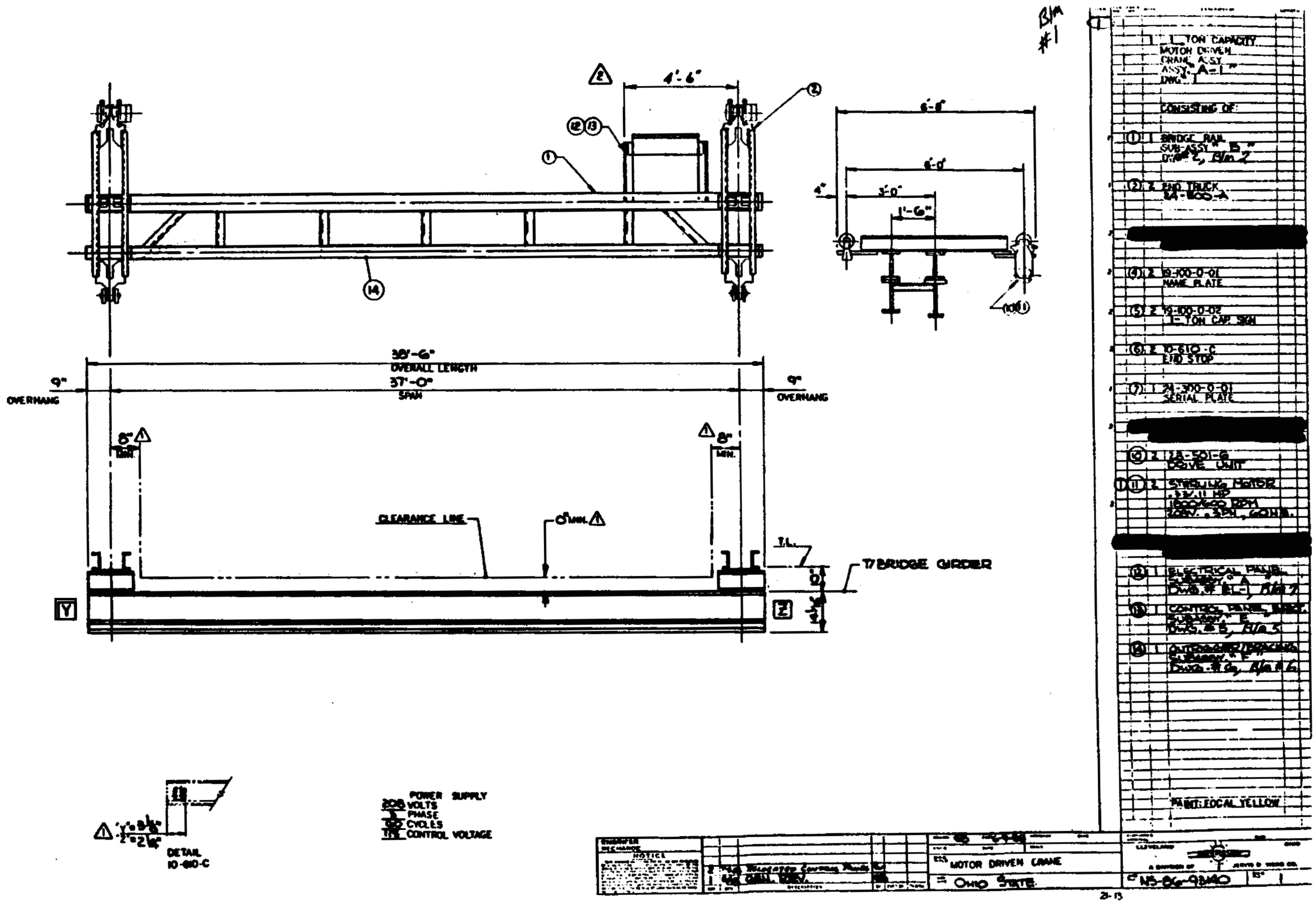

Figure 5.2: Underhung bridge crane drawing, motor drive.

Chapter 6

Conclusions

The use of an underhung bridge crane requires a good deal of design consideration and modification. The underhung bridge crane has been serving the chamber in a wide variety of ways since September 1986, and we are continuing to discover new uses for the crane in electromagnetic measurements.

One area that we feel could have been better designed is the speed control system. We feel that a continuously variable speed system for all motors in all axes of movement would be extremely desirable. One possible way to achieve this goal would be the use of electronic motor control systems such as the SCR based systems currently available. The area that might be more difficult is the remote control of such a fully variable system, but we feel that such control would likely be worthwhile.

Bibliography

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[2] Rueland Electric, Electronic Controls Division, 17969 E. Railroad Street, Industry, CA. 91749.

[3] Telemotive, A Dynascan Corporation, 6460 West Cortland Street, Chicago, Ill. 60635

[4] W. W. Grainger, Inc.

[5] Aeroquip, Industrial Division, 1225 W. Main Street, Van Wert, OH 45891
(Dealer: Hydron, Inc. 2550 W. Fifth Ave, Columbus, OH 43204)

[6] Spanmaster, A Division of Jervis B. Webb Company, 739 Moore Road, Avon Lake, OH 44012

[7] Ohio Crane & Hoist Company, 463 W. Town Street, Columbus, OH 43215